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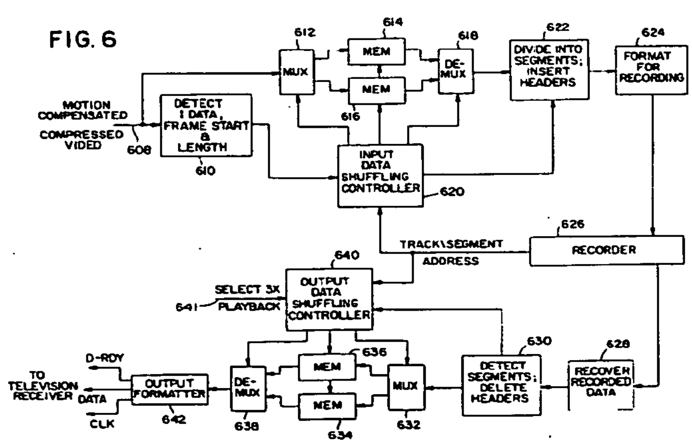
## (54) Digital high definition video recorder having high definition display in trick-play modes.

(57) A digital video tape recorder records compressed image signals which include both intra-frame encoded image slices and motion compensated encoded image slices. The recorder receives the encoded data either in a format in which a portion of each frame is encoded using intra-frame techniques or in a format in which an entire frame of a group of frames is encoded using intra-frame techniques. Shuffling circuitry in the recorder recognizes the intra-frame encoded slices and reorders the slices as they are recorded such that a substantial portion of the intra-coded image slices will be recovered both in normal play mode and in trick play mode. For the one signal, these slices represent the intra-coded portion of each frame; for the other signal they represent the one intra-coded frame in the group of frames. In one embodiment of the invention, the trick-play mode is a three-times forward speed mode and the intra-coded slices are arranged such that substantially all of the intra-coded slices are recovered in trick-play mode.

FIG. 6

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## BACKGROUND OF THE INVENTION

The present invention relates to a video tape recorder for recording high definition television (HDTV) signals and in particular to a recorder which records motion compensated compressed high definition television signals and yet allows a high definition display to be produced in trick-play modes.

Digital high definition television production schemes have been under development for several years. These schemes typically produce higher quality television images and sound than conventional television systems. To do this, these systems convey more information than is conveyed in a conventional television signal.

Recent regulations issued by the Federal Communications Commission (FCC), however, require that this larger amount of information be sent within the same band of frequencies as a conventional television signal. To fit the relatively large band width High Definition Television (HDTV) signal into a standard television channel, the information content of the HDTV signal must be compressed.

Because of the relatively large degree of spatial redundancy and temporal redundancy in the HDTV signals, relatively high levels of data compression can be achieved in most television signals.

One method by which spatial redundancy is removed from a television signal is to generate a discrete cosine transform representation of the image. This representation resolves an image frame into coefficient values representing its various spatial frequency components. Portions of an image which are the same from pixel to pixel or which exhibit a repetitive pattern are resolved from many pixel values to a relatively small number of frequency coefficient values. In addition, since the human eye is less sensitive to quantization errors in image components having high spatial frequencies than in image components having relatively low spatial frequencies, the high spatial frequency coefficients may be coarsely quantized to further reduce the amount of data used to represent the image.

Temporal redundancy in an image is removed by encoding only the areas of a given frame which are different from corresponding areas of a previously encoded frame. This is generally known as predictive coding. Temporal redundancy can be further exploited to achieve even higher levels of data compression by performing motion compensation. Using this scheme, before a image block is encoded, the blocks surrounding it in a previously encoded frame are searched for one block which most closely matches the block in the current frame. The current block is then subtracted from the matching block in the previous frame. The spatial frequency coefficient values are generated based upon the differences between the two image blocks. Exemplary video image compression systems which employ motion-compensated predictive encoding techniques are 1) that proposed by the Motion Picture Experts Group (MPEG) and described in the document entitled "Coded Representation of Picture and Audio Information" ISO-IEC/JTC1/SC2/WG11 N0010 MPEG 90/41 dated July 25, 1990; and 2) the DigiCipher™ System, described in section 25.5 of the Television Engineers Handbook by K.B. Benson et al., McGraw Hill, 1992, pp. 2532-2543.

Other encoding techniques are also used in the MPEG and DigiCipher systems such as run-length coding, in which strings of identical values are encoded as a smaller number of values; and variable length coding, in which frequently occurring data values are assigned a digital code value having fewer bits than the code value assigned to less frequently occurring data values.

Regardless of the encoding technique, the encoded HDTV signal must be decoded before it can be displayed. For predictively encoded or motion compensated predictively encoded HDTV signals, the decoding apparatus may include one or more frame memories which hold images that have already been decoded. The pixel values held by these memories are used to reconstruct the predictively encoded data in the current frame.

Using either MPEG or DigiCipher encoding techniques, HDTV signals having a data rate of between 600 and 1200 Megabits per second (Mbps) can be compressed to produce a signal having a data rate of less than 20 Mbps. As with other terrestrial broadcast signals, consumers will want to be able to receive, display and record signals representing high resolution video images with little no loss of resolution.

On first analysis, the compression of HDTV signals should be beneficial for recording the signals on home use Video Tape Recorders (VTR's), since these units typically have only a limited bandwidth available for recording video signals. For example, a paper by C. Yamamitsu et al. entitled "A Study on Trick-plays For Digital VCR", IEEE Transactions on Consumer Electronics, Volume 37, No. 3, August, 1991, PP. 261-266, discloses a home use VCR having a recording rate of 27 Megabits per second (Mbps). A typical HDTV signal, prior to encoding, has a bit-rate of 600 Mbps. Compression methods such as MPEG or DigiCipher can reduce these HDTV signals to have a bit-rate of approximately 18 Mbps without noticeably degrading the image quality when the compressed signal is expanded.

The problem with predictively encoded HDTV signals does not occur in recording or in normal playback modes but in trick-play modes such as fast-forward and reverse in which the video image is displayed at a higher rate than that at which it was recorded.

The problem is illustrated in Figures 1 and 2. Figure 1 shows the track scanning sequence of pre-recorded video information during normal playback. As shown in Figure 1, slices of the video image 110, 112 and 116 are scanned in sequence as the tape head moves along the track 115. Each of these slices represents the same number of pixels in the reproduced image. As shown in the figure, however, the amount of data in a slice may vary from slice-to-slice. This variation in the amount of data in a slice occurs because of the relative coding efficiencies of the slices in the original HDTV signal. Slices which represent still portions of a multi-frame image or which represent portions having relatively little variation may be encoded using a relatively small number of data values. Image portions containing a high level of detail and having no corresponding portions in previously encoded frames may require a significantly larger number of data values when they are encoded.

When the image signals are read from the tape during normal playback each slice of each frame is read from the tape in sequence as indicated by the arrows 118 and 120. If the coding method which produced the HDTV signals used predictive coding techniques the recorded data includes both intra-frame coded data such as that shown by the shaded tracks of Fig. 1 and predictively coded data such as that shown as unshaded tracks of Fig. 1. In normal playback as the data is removed from the tape the pixel values produced from the intra-frame encoded data are stored in a memory and are available for use in reconstructing the predicted frames.

Figure 1 illustrates the track scanning sequence during a fast-forward trick-play mode. In this mode, instead of sequentially taking the slices 110, 112 and 116 the slices recovered are in sequence 110, 112, 122 and 124. As shown in this figure, some slices, for example, slices 116 and 120 are never recovered from the tape. If some of these slices (e.g. 116) contain intra-coded data then their corresponding pixel values will not be available when corresponding slices (e.g. 130 and 132) of a predicted frame, which is based on the intra-coded frame, are read from the tape. Consequently it may not be possible to properly reconstruct the predicted frame for display.

Because of the difficulties of recovering predicted frames in trick-play modes most of the proposed methods for recording digitally compressed (bit-rate reduced) signals have restricted the encoding techniques that are used to encode data for recording on VTR's to exclude predicted frames. Exemplary systems of this type are described in an article by C. Yamamitsu, et al. entitled "An Experimental Study for a Home-Use Digital VTR", IEEE Transactions on Consumer Electronics, Volume 35, No. 3, August 1989, PP. 450-457, and in a paper by J. Lee et al., entitled "A Study on New DCT-Based Bit Rate Reduction Algorithm and Variable Speed Playback For A Home-Use Digital VCR", IEEE Transactions on Consumer Electronics, Volume 38, No. 3, August 1992, PP. 236-242. As described above, since these systems do not use predicted frames, they cannot compress data with the efficiency of a system which does use predicted frames. Consequently, for the same compressed data rate, they cannot achieve the same levels of detail in the reproduced image as a system, such as MPEG, which uses motion-compensated predictive coding techniques.

## SUMMARY OF THE INVENTION

The present invention is embodied in a digital video tape recorder (DVTR) which records motion compensated encoded high definition television signals. Compressed video signals to be recorded are processed to separate intra-frame encoded data from motion compensated encoded data. The intra-frame coded data is then interleaved with the motion compensated data and recorded at positions on the tape such that a substantial portion of the intra-frame coded data will be recovered in certain pre-defined trick-play modes.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 (prior art) is a graphical representation of a segment of video tape containing data encoded according to the DigiCipher standard, which illustrates the scanned path of the video heads in normal and three-times (3x) fast-forward modes.

Figure 2 is a graphical representation of a segment of video tape which contains the same signal as shown in Figure 1 but recorded using apparatus which embodies the present invention.

Figure 3 is a graphical representation of a segment of video tape which is useful for describing how recorded segments of video information may be recovered.

Figure 4 (prior art) is a graphical representation of a segment of video tape which illustrates how data representing a group of frames (GOF) recorded according to the MPEG standard may be recorded on a DVTR.

Figure 5 is a graphical representation of a segment of video tape which illustrates how the

signal shown in Figure 4 may be recorded using apparatus in accordance with the subject invention.

Figure 6 is a block diagram of a DVTR which includes an embodiment of the present invention.

## DETAILED DESCRIPTION

The present invention concerns a method for recording compressed video in a manner which allows for high resolution display in trick-play modes. Although it is not limited to these systems, the invention is described in terms of the DigiCipher and MPEG encoding methods. In order to fully understand the invention, it is helpful to first understand how the data is encoded according to these standards.

The DigiCipher system encodes video using both intra-frame coding and motion-compensated predictive coding. In each frame, a portion of the image is intra-frame coded and the remainder is coded using motion adaptive techniques. Both the intra-frame and predictively encoded portions utilize discrete cosine transforms and variable length codes to produce the compressed image data. The intra-frame coded portion of the image changes from frame to frame so that the entire image is periodically refreshed. This limits undesirable propagation of the errors through the predictively encoded portions of the frame.

Figure 1 is a diagram of an exemplary tape format for recording four frames of the DigiCipher signal. For convenience, the Figure shows each frame as occupying nine tracks, one image slice per track, and only one slice in each frame (indicated by the shaded track) contains intra-frame coded data. In this exemplary tape format each track of the tape corresponds to a horizontal slice of the image. As shown in Figure 1 the intra-frame encoded slice advances by one image slice from frame-to-frame.

In an actual recorded signal, the compression efficiency changes depending on the spatial frequency content of the image. Accordingly, an individual frame may use more than nine tracks or less than nine tracks. In addition where nine tracks are needed, the intra-frame coded portion of the image frame may occupy more than one track or less than one track.

The problem with recovering and displaying recorded video information which is encoded using the DigiCipher standard occurs in trick-play modes. In these modes, for example fast-forward and reverse, the tape-head does not follow the tracks as indicated by the arrows 118 and 120 of Figure 1 but instead follows a path which crosses several tracks as illustrated by the arrows 119 and 121. As described above, only intra-coded data may be recovered for display in trick-play mode. As shown in Figure 1, only a very small amount of video data would be recovered in a three times (3x) forward mode, illustrated by the arrows 119 and 121.

Figure 2 is a block diagram of an alternative tape formatting method suitable for use with the DigiCipher encoding technique which would allow high resolution images to be displayed during specific trick-play modes. As shown in Figure 2, each of the intra-frame coded blocks is divided into multiple smaller blocks which are then recorded at specific positions on the tape so that they will be recovered in sequence as the head crosses the tape in specific trick-play modes. In the exemplary tape format a trick-play mode of three times (3x) forward speed is illustrated by the arrows 119 and 120 and a mode of six times (6x) reverse speed is indicated by the arrows 122 and 124.

As shown in Figure 2 essentially all of the intra-coded data is recovered in the 3x forward speed mode and half of the intra-coded data is recovered in the 6x reverse mode. Recall, however, that the intra-coded data in any given frame represents only a portion of that frame, in this example a slice or segment corresponding to one-ninth of the image. Thus, in one frame period at 3x forward speed, three-ninths or one-third of an image (i.e. three slices from three respectively different frames) would be recovered. The remaining two-thirds of the image would be displayed from earlier frames. Thus, the trick-play display in 3x forward speed would consist of nine slices or segments from nine respectively different frames. This display, however, would be at the full resolution of the high definition image.

As described above, each of the intra-frame encoded segments 110, 112 and 116 may be of different length. These segments are encoded such that they reproduce a specific sized block of pixels in the final image. Where the image area represented by a block contains a relatively large amount of high spatial frequency image components, the intra-frame encoded data used to represent that block may be larger than for a block which represents an area having low level of detail. When a block is larger than may be scanned by the head in trick-play mode, as indicated by the area 110a appended to block 110, the block is recorded such that the start of the block will be recovered in trick-play mode. The pixels represented by the data which cannot be recovered may be obtained from the earlier frame or, alternatively, may be filled in with a neutral color for example, gray.

Figure 3 shows the path of the head in trick-play mode in order to illustrate how the data blocks may be recovered. In Figure 3 the tape is rotated so that the head track is roughly horizontal. The triangles 320, 322 and 324 illustrate times when

image data can and cannot be recovered from the tape due to the head crossing a track. The shaded areas 310 of the triangles represent times when image data cannot be recovered because data is available from two tracks simultaneously and at low levels. The areas 312, on the other hand, represent times when data at a relatively high level is available from a single track. As shown by the dotted lines 330, the positions of the segments 110, 112 and 116 are aligned with the times 320, 322 and 324 at which the tape head may recover data in the 3x forward trick-play mode.

While it is desirable to simply rearrange the intra-frame encoded and motion compensated encoded segments as they are received, it may be difficult to both maintain the integrity of the segments and to record the intra-coded data at the preferred locations on the tape. Accordingly, it is contemplated that individual segments which were encoded using motion compensation encoding techniques may be split, and an intra-frame encoded segment inserted between the parts of the split segment when the data is recorded on the tape. Of course, this splitting of segments would necessarily be reversed when the data is processed for display after it is recovered from the tape.

Alternatively, due to the relatively large bandwidth that is available for digital signals (e.g. 25 MHz) and the relatively small bandwidth of the encoded digital signal (e.g. 18 MHz), it may be preferable to encode the image data at this higher bandwidth, in order to make room for an intra-coded segment at the proper location on the tape. Due to the extra bandwidth, it may be possible to "move" encoded image segments on the tape to make room for the intra-frame encoded segments at their desired positions.

Returning to Figure 2, the tape head is maintained in proper alignment during trick-play modes to recover the data by using a timing track 210. The exemplary timing track 210 provides a series of marks 210a which indicate the starting head-scan positions for the tape heads to recover the maximum amount of data in the chosen trick-play mode. It is noted that only specific trick-play speeds are accommodated by the particular tape format. This should not be a problem, however, since most conventional home-use video tape recorders only allow for one trick-play viewing mode in forward speed and one in reverse speed.

Figure 4 is a tape format diagram which illustrates how image data from a group of eight frames encoded according to the MPEG standard may be recorded on tape. The particular group of frames (GOF) consists of a single intra-coded frame (I-frame), frame 1; six bidirectionally encoded frames (B-frames), frames 2-7; and one predictively encoded frame (P-frame), frame 8. Of these frames, only the data in frame 1 may be reliably recovered by the VTR in trick-play mode. Frames 2-8 contain motion compensated predictively encoded data which cannot be reliably recovered in the trick-play modes due to the absence of data on which the prediction was based, as described above.

It is noted that the frames as received and recorded are not in order. Frame 8 follows frame 1 which is followed in sequence by frames 2, 7, 3, 6, 4 and 5. This is a typical transmission sequence for an MPEG group of frames (GOF). In a typical MPEG receiver, the frames shown in figure 4 would be decoded as follows. First, frame 1 would be received, decoded and stored into a memory. While frame 1 was being decoded, frame 8 would be received and stored temporarily. After frame 1 has been decoded, frame 8 would be processed as predicted data based on the stored frame 1. Next, each of the frames 2, 7, 3, 6, 4 and 5 would be bidirectionally decoded using data in the stored frames 1 and 2.

It is noted that according to this scheme frame 1 remains in the memory of the receiver until all of the frames 1-8 have been decoded. In this exemplary embodiment as the frames are decoded they are made available for display. The frames are displayed, however, in sequence with frame 1 being displayed first and frame 8 being displayed last.

Figure 5 is a tape format diagram which illustrates how the MPEG encoded data may be rearranged to allow for high resolution display in trick-play modes. According to this scheme the data from the one intra-coded frame is divided into blocks 510 which are distributed along the tape at positions which will be scanned by the tape head in the defined trick-play modes. As shown in Figure 5, substantially all of the intra-coded image will be recovered in the 3x forward trick-play mode and approximately one-half of the image will be recovered in the 6x reverse play mode.

Figure 6 is a block diagram of exemplary circuitry which may be used to implement the tape encoding schemes shown in figures 2 and 5. Compressed video signals which include both intra-frame coded data (IDATA) and motion compensated predictively encoded data (MCDATA) are applied, via a terminal 608, to a multiplexer 612 and to circuitry 610 which detects the start and length of each frame and the position of any IDATA in the frame. In the DigiCipher encoding method, image slices which are represented by IDATA are identified in the data sequence. This may be, for example, by values in their respective slice header records.

Information recovered by the circuitry 610 is applied to an input data shuffling controller 620.

The controller 620 generates the control signal for the multiplexer 612 causing it to direct the compressed video data to either one of two memories 614 or 616. In a first embodiment of the invention, one suitable for processing data which is encoded according to the DigiCipher standard, each of the memories 614 and 616 is large enough to hold a single compressed frame. As set forth above, however, compressed frames may be of different lengths. Assuming that the average length of a compressed frame is nine tracks, a memory having sufficient storage space to hold data on 27 tracks should be sufficient for either of the memories 614 or 616.

The memories 614 and 616 are coupled to the data inputs of a demultiplexer 618. The demultiplexer 618 is also controlled by the input data shuffling controller 620 to provide data that is read from one of the two memories 614 and 616. The data read from the memories 614 and 616 is determined by address values which are provided by the controller 620. Controller 620 is also responsive to track/segment addresses provided by the recorder 626. These addresses identify the position on the tape at which data will be recorded, and, so, allow the controller to read the IDATA segments from the appropriate memory 614 or 616 so that they will be recorded at the specific locations on the tape shown in Figure 2.

In the exemplary embodiment of the invention, the controller 620 generates a table for each input frame which identifies the encoded segments or slices as they are stored in the memory. This table is maintained in a memory (not shown) which is internal to the controller 620. The controller 620 uses this table and the track/segment address from the recorder 626 to provide either an IDATA segment or an MCDATA slice from the stored frame at the appropriate time to generate a recorded image format such as that shown in Figure 2.

In this exemplary embodiment of the invention, the memories 614 and 616 are operated as ping-pong random-access buffers. Data is received in sequence into one of the memories 614 and 616 via the multiplexer 612 while data is provided as specifically accessed blocks from the other one of the memories 616 or 614, via the demultiplexer 618. Since each of the memories 614 and 616 holds one compressed frame, the output signal provided by the demultiplexer 618 is a sequence of segments in which the intra-frame coded data is distributed among the motion compensated predictively encoded data as illustrated in Figure 2.

The data provided by the demultiplexer 618 is applied to circuitry 622 which divides the data into segments and inserts headers. These headers identify each data segment as being either IDATA or MCDATA and indicate the length of the data segment and the position of the decoded pixels in the resulting frame.

The circuitry 622 relies on information provided by the data input shuffling controller 620 to generate these headers. As the controller 620 reads successive segments from the memories 614 and 616 according to the tape format shown in Figure 2, it provides a signal to the circuitry 622 which indicates the type and length of the data segment being provided. The circuitry 622 generates appropriate header information for the segments and applies the resulting data stream to circuitry 624 which formats the data for recording. The circuitry 624 may include for example an error correction code (ECC) encoder (not shown), a channel encoder (not shown) and a recording amplifier (not shown). Signals provided by the circuitry 624 are recorded onto the tape by the recorder 626 to realize the tape format shown in Figure 2.

During normal playback and playback during trick-play modes, data is read from the tape by the recorder 626 and applied to circuitry 628 which recovers the recorded data from the signals read from the tape. The circuitry 628 may include for example a head amplifier (not shown) a detector (not shown) and an ECC decoder (not shown). The output signal of the circuitry 628 is a digital data stream which is applied to circuitry 630 which detects the segments and deletes the header information that was inserted by the circuitry 622. The circuitry 630 also generates a signal indicating when a new segment is being processed. This signal is applied to output data shuffling control circuitry 640.

The output data stream provided by the circuity 630, the encoded data without the header information, is applied to a multiplexer 632. The multiplexer 632 is controlled by a signal provided by the output data shuffling controller 640 to apply the input signals to either one of the memories 634 and 636. The controller 640 is also coupled to the memories 634 and 636 to control the addresses into which the data is stored and from which the data is read. Data read from the memories 634 and 636 is applied to a demultiplexer 638 which is also controlled by the data output shuffling controller 640.

The output data stream provided by the demultiplexer 638 during normal play mode is that shown in Figure 1. The intra-frame encoded data is restored to its proper position in the data stream as defined by the DigiCipher encoding method. This signal is applied to an output formatter 642 which generates three signals, a data ready signal (D-RDY), a data signal (DATA) and a clock signal (CLK). These signals are applied to a television receiver as if they were received broadcast video signals. The data is reformatted from the recorded

format shown in Figure 2, to the standard DigiCipher format shown in Figure 1, by the output shuffling controller 640. In the exemplary embodiment of the invention, the controller 640 stores data into one of the memories 634 and 636 in sequence and reads data from the other memory segment by segment in order to restore the data to the format shown in Figure 1.

The memories 634 and 636 may be identical to the memories 614 and 616 described above. Each of these memories is large enough to hold one compressed frame video signal. The memories are controlled by the controller circuitry 640 to operate as ping-pong random-access buffers; one of the memories 634 and 636 is receiving data while the other memory 636 and 634, is used to provide data to the output formatter 642 via the demultiplexer 638.

The output data shuffling controller 640 is also responsive to a signal 641 which indicates that 3x forward or 6x reverse playback has been requested. Responsive to this signal the controller 640 will monitor the track/segment address provided by the recorder 626 and the data provided by the circuitry 628 to determine when intra-frame encoded data is being provided by the tape. In this trick-play mode, only this intra frame encoded data is recorded in the memory 636 or 634. Since this data may be provided sporadically to the television receiver, the output formatter 642 will generate its D-RDY signal to be high only when a valid intra-frame coded data is being provided to the television receiver.

The same circuitry with minor modifications may be used to process data which is encoded according to the MPEG standard, as shown in figures 4 and 5. The main differences in the circuitry for processing MPEG data as opposed to circuitry for processing DigiCipher data is in the size of the memories 614, 616, 634 and 636 and in the operation of the input and output data shuffling controllers 620 and 640. In this second exemplary embodiment of the invention, each of the memories 614, 616, 634 and 636 has a sufficient number of storage cells to hold an entire group of frames of the MPEG encoded data. In the example shown in figures 4 and 5, an average group of frames would be stored in 72 tape tracks. The number of tracks needed to represent a given group of frames may vary depending upon the efficiency with which the underlying image may be compressed. It is contemplated however, that a memory having a sufficient number of storage cells to hold 150 tape tracks would be sufficient for any of the memories 614, 616, 634 or 636.

The input data shuffling controller 620 used in this embodiment of the invention would rearrange the data from the format shown in Figure 4 to that shown in Figure 5. The one encoded I-frame at the beginning of the group of frames is divided into blocks which are then distributed among the encoded blocks in the remainder of the group of frames. During normal replay, the output data shuffling controller 640 would rearrange the data, as stored in the format shown in Figure 5, to produce an output signal which is consistent with the format shown in Figure 4. Both of these reformatting operations are performed by storing the data into one of the ping-pong memories in sequence, as it is received, while monitoring and building a table which matches the individual segments to their locations in the memory. When data is read out, it is rearranged so that the intra-frame encoded information is in a different position. This position is determined from the table which was developed when the data was stored in the memory.

While the invention has been described with reference to the DigiCipher system and the MPEG encoding standard, it is contemplated that it may be used with other systems such as the DSC-HDTV system proposed by Zenith/AT&T.

While the invention has been described in terms of exemplary embodiments it is contemplated that it may be practiced as outlined above within the spirit and scope of the appended claims.

## Claims

1. A digital video tape recorder having at least one tape head for recording video data onto a tape, the video tape recorder having a normal play mode and a trick play mode, wherein the tape head follows a first track across the tape in the normal play mode and a second, different track across the tape in the trick play mode, the digital video tape recorder comprising:

   means for receiving a sequence of the video data representing encoded slices of successive frames of a video image, wherein some slices of the successive frames have been encoded using intra-frame encoding techniques and other slices of the successive frames have been encoded using motion compensated encoding techniques;

   identifying means for separately identifying the respective intra-frame encoded slices and the motion compensated encoded slices of each of the successive frames of the video image and for separating the intra-frame encoded slices and the motion compensated encoded slices into respectively different data streams;

   means for reformatting the motion compensated encoded data stream into blocks having a substantially fixed size;

   means for reformatting the intra-frame en-

coded data stream into blocks having a substantially fixed size;

recording means for recording the intra-frame encoded blocks and the motion compensated encoded blocks on the tape; and

shuffling means, coupled between the identifying means and the recording means, for changing the relative order in which the blocks of the intra-frame encoded data stream and the motion compensated encoded data stream appear in the video data sequence to position the intra-frame encoded blocks on the tape such that the tape head passes over at least one-half of the intra-frame encoded blocks of the one frame in both the normal play mode and in the trick play mode.

2. A digital video tape recorder according to claim 1, wherein:

the encoded data received at the means for receiving includes a first contiguous group of slices which are encoded using intra-frame techniques and a second contiguous group of slices of each one of the successive frames which are encoded using motion compensated encoding techniques; and

the shuffling means includes means for interleaving ones of the intra-frame encoded blocks of the one frame among ones of the motion compensated encoded blocks such that, when the interleaved blocks are recorded on the tape, the tape head will pass over at least one-half of the intra-frame encoded blocks of the one frame in both the normal play mode and the trick-play mode.

3. A digital video tape recorder according to claim 2, wherein the digital video tape recorder has two heads, the trick-play mode is a three-times forward play mode and the shuffling means interleaves the intra-frame encoded blocks of the one frame among the motion compensated encoded blocks such that the tape heads pass over substantially all of the intra-frame encoded blocks of the one frame in both the trick-play mode and in the normal play mode.

4. A digital video tape recorder according to claim 3, wherein the recording means records a timing track which is used in trick-play mode to align the tape-heads with a preferred path across the tape, which preferred path contains the recorded intra-frame encoded image blocks of the one frame.

5. A video tape recorder according to claim 4, further including:

data recovery means for recovering the recorded data from the tape;

output shuffling means for identifying the interleaved intra-frame encoded blocks of the one frame from among the recovered data and for rearranging the identified blocks and the motion compensated encoded blocks to produce an output signal during normal play mode which has the identified intra-frame encoded blocks of the one frame and the motion compensated encoded blocks of the one frame arranged in an order equivalent to that of the encoded data received by the means for receiving.

6. A digital video tape recorder having at least one tape head for recording video data onto a tape, the video tape recorder having a normal play mode and a trick play mode, wherein the tape head follows a first track across the tape in the normal play mode and a second, different track across the tape in the trick play mode, the digital video tape recorder comprising:

means for receiving a sequence of the video data representing encoded slices of individual frames of a group of successive frames such that the group of frames includes at least one frame in which each slice is encoded using intra-frame encoding techniques and other frames of the group of frames are encoded using a motion compensated encoding technique; and

identifying means for separately identifying the respective intra-frame encoded slices and the motion compensated encoded slices of each of the successive frames of the video image;

recording means for recording the intra-frame encoded slices and the motion compensated encoded slices on the tape; and

shuffling means, coupled between the identifying means and the recording means, for interleaving the intra-frame encoded slices from the one frame among the slices of each of the other frames in the group of frames such that, when the interleaved slices are recorded by the recording means, the tape head will pass over at least one-half of the intra-frame encoded slices from the one frame in both the normal play mode and in the trick-play mode.

7. A digital video tape recorder according to claim 6, wherein the digital video tape recorder has two tape heads, the trick-play mode is a three-times forward play mode and the shuffling means interleaves the intra-frame en-

coded slices among the motion compensated encoded slices such that the tape heads pass over substantially all of the intra-frame encoded slices in both the trick-play mode and in the normal play mode.

8. A digital video tape recorder according to claim 7, wherein the recording means records a timing track which is used in trick-play mode to align the tape-heads with a preferred path across the tape, which preferred path contains the recorded intra-frame encoded image slices from the one frame.

9. A video tape recorder according to claim 8, further including:

   data recovery means for recovering the recorded data from the tape;

   output shuffling means for identifying the interleaved intra-frame encoded slices among the recovered data and for rearranging the identified slices and the encoded slices, representing frames in the group of frames other than the one frame, to produce an output signal during normal play mode which has the encoded slices of the group of frames in an order substantially equivalent to that of the encoded data received by the means for receiving.

10. A digital video tape recorder according to claim 9, wherein the output shuffling means includes means for providing the identified intra-frame encoded slices relatively exclusive of any other slices as the output signal during the trick-play mode.

11. A method for recording image data on a tape using a digital video tape recorder having at least one tape head, the video tape recorder having a normal play mode and a trick play mode, wherein the tape head follows a first track across the tape in the normal play mode and a second, different track across the tape in the trick play mode, the method comprising the steps of:

   receiving a sequence of the image data representing encoded slices of successive frames of a video image, wherein at least one frame of the successive frames of the video image has been encoded using intra-frame encoding techniques and other frames of the successive frames of the video image have been encoded using motion compensated encoding techniques;

   separately identifying the respective intra-frame encoded slices and the motion compensated encoded slices in the received sequence of data values;

   recording the intra-frame encoded slices and the motion compensated encoded slices on the tape; and

   changing the order of the identified intra-frame encoded slices and motion compensated encoded slices in the sequence of image data prior to recording to interleave the intra-frame encoded slices of the one frame among the motion compensated encoded slices of the other frames to produce a reordered data sequence such that, when the reordered data sequence is recorded on the tape, the tape head passes over at least one-half of the intra-frame encoded slices in both the normal play mode and in the trick play mode.

FIG.1
PRIOR ART

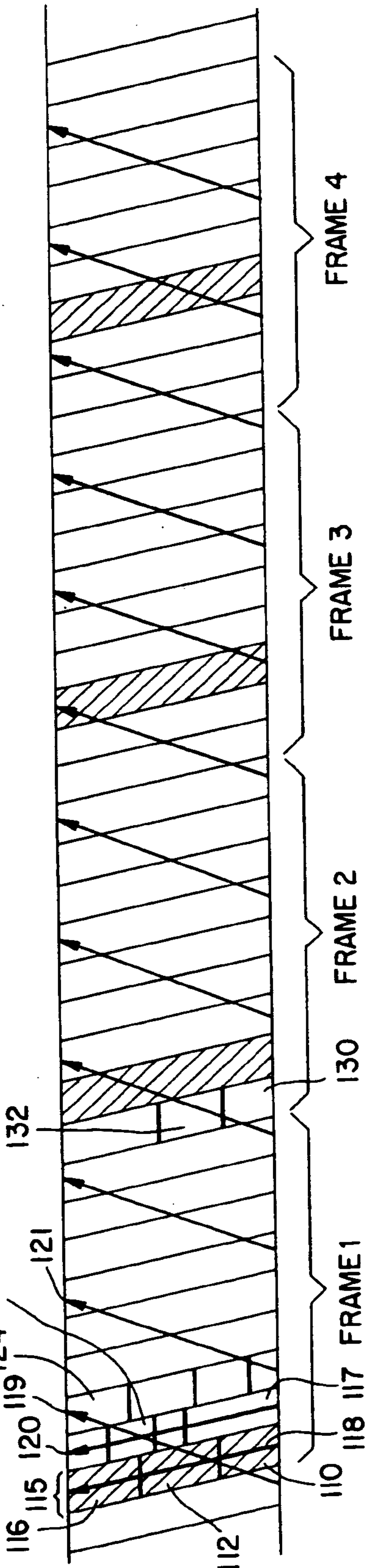
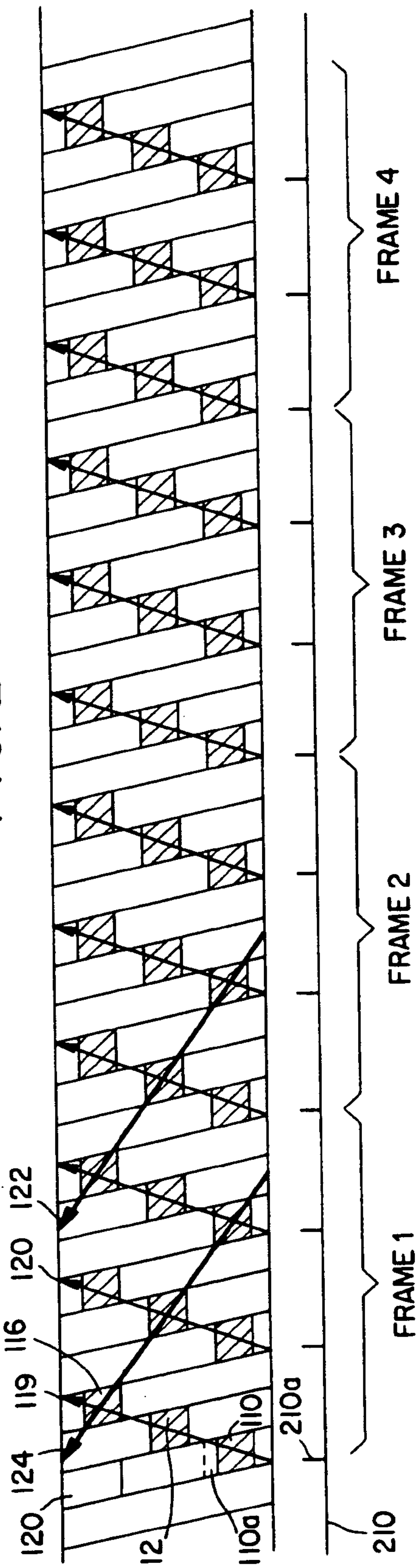
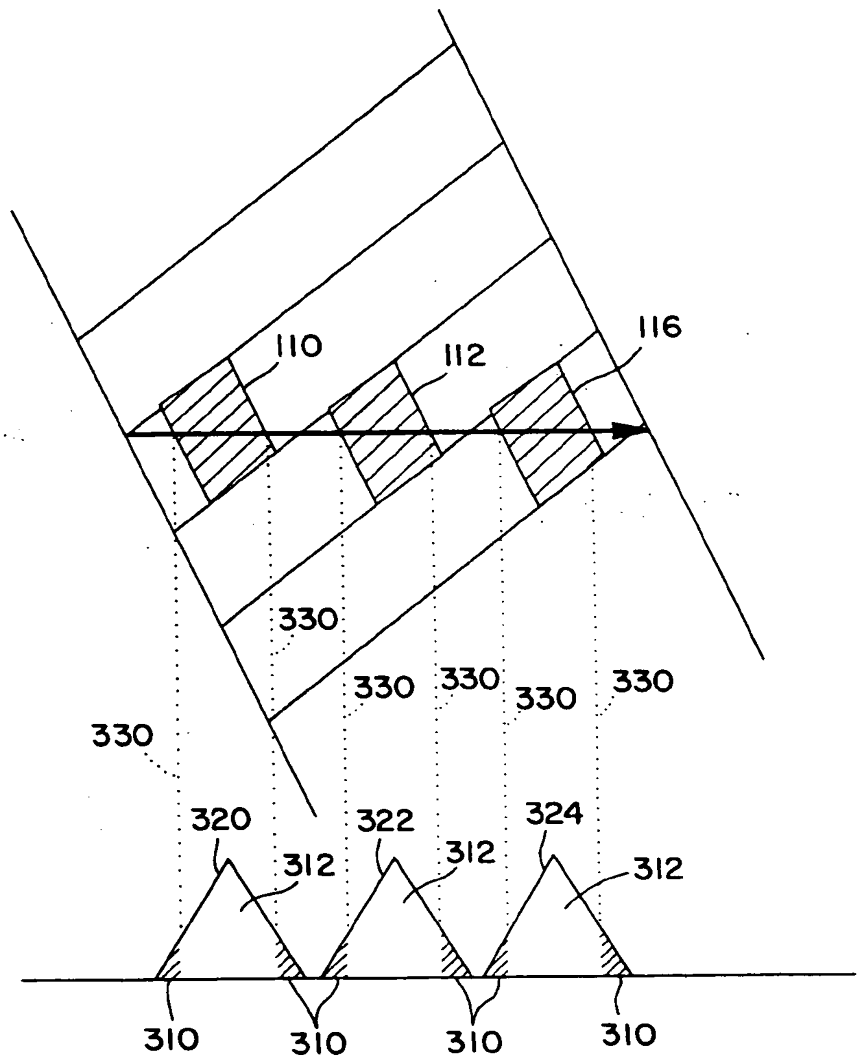



FIG. 2




110
112
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310

FIG. 3

FIG. 4 PRIOR ART

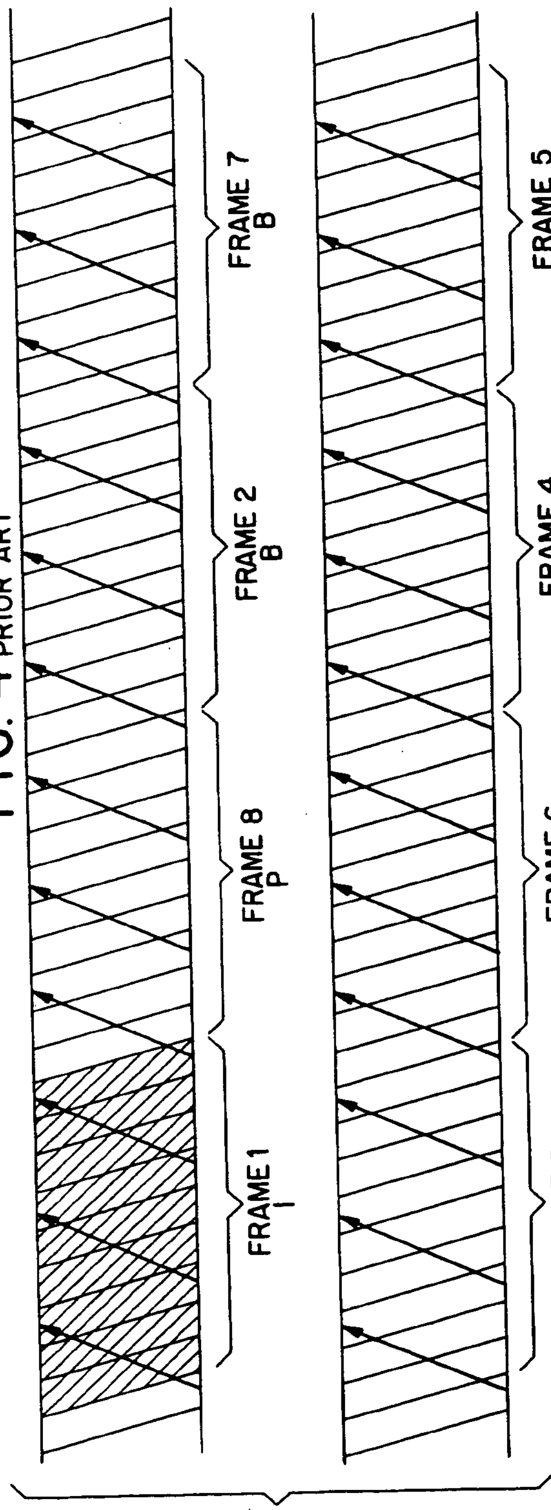
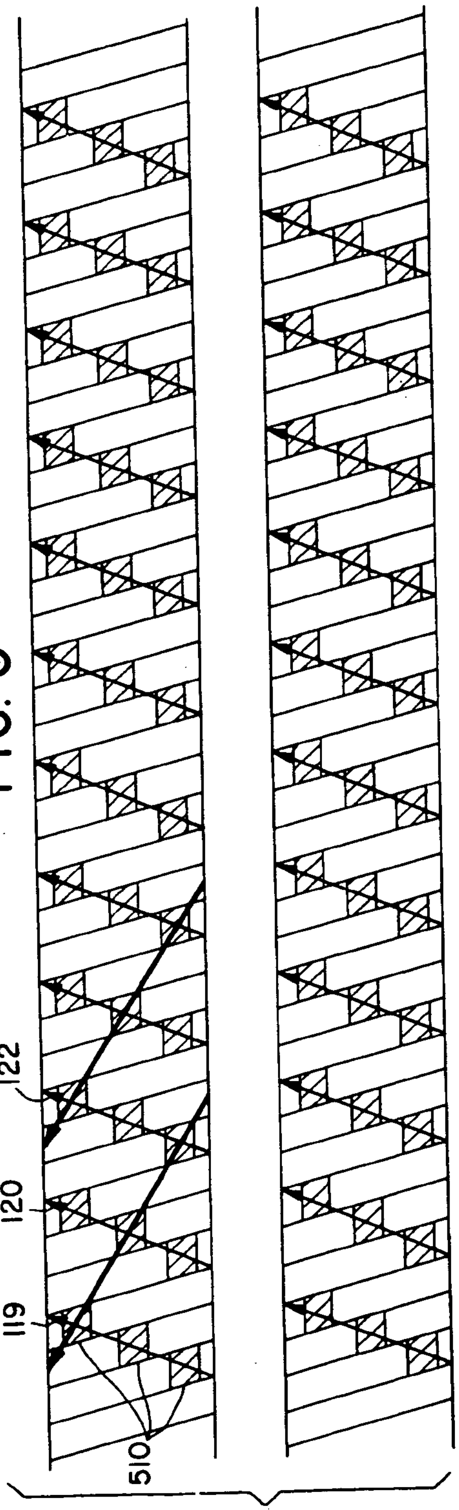



FIG. 5



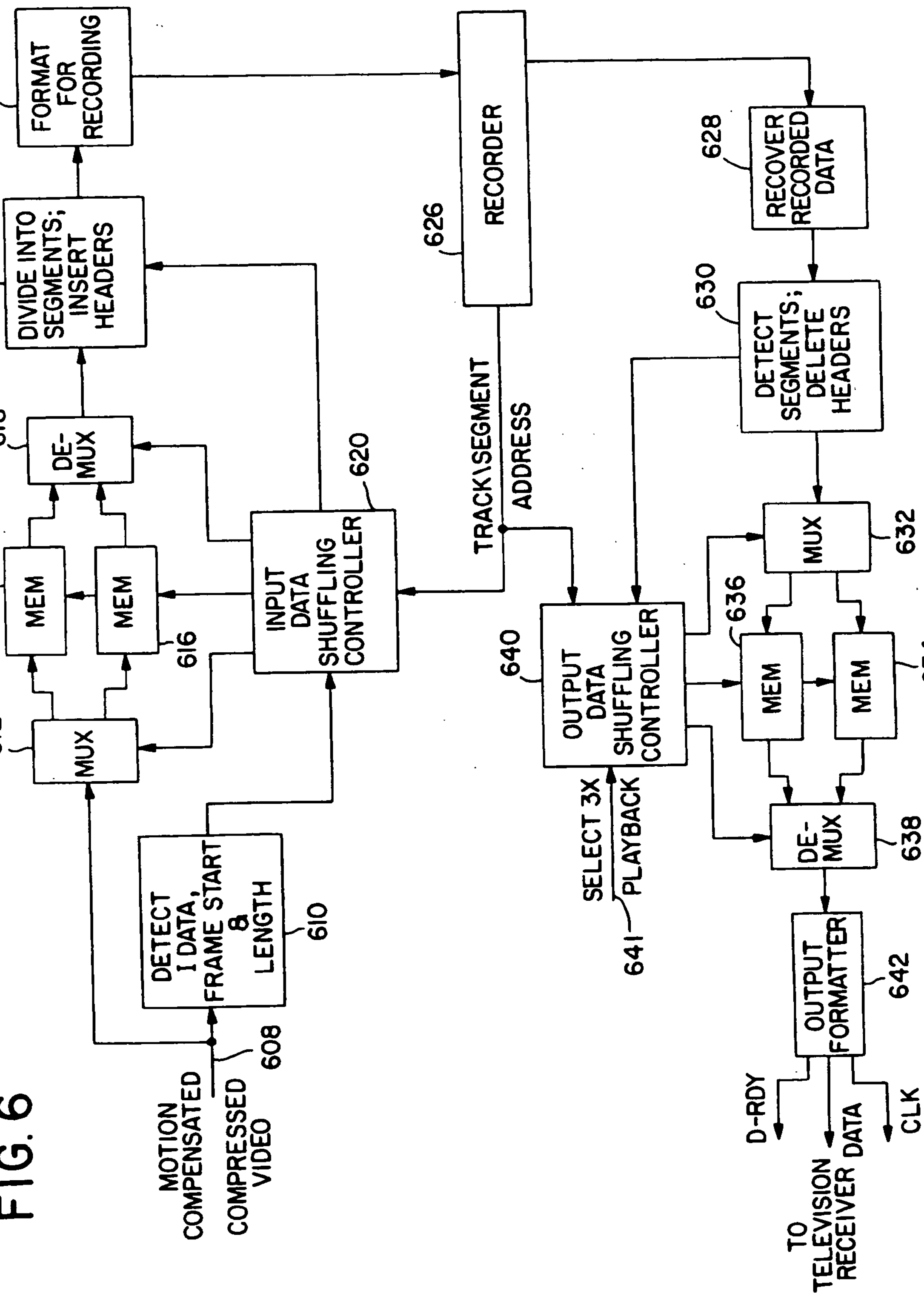

MOTION COMPENSATED COMPRESSED VIDEO
608
DETECT I DATA, FRAME START & LENGTH
610
MUX
612
MEM
614
MEM
616
DE-MUX
618
INPUT DATA SHUFFLING CONTROLLER
620
DIVIDE INTO SEGMENTS; INSERT HEADERS
622
FORMAT FOR RECORDING
624
RECORDER
626
TRACK\SEGMENT ADDRESS
RECOVER RECORDED DATA
628
DETECT SEGMENTS; DELETE HEADERS
630
MUX
632
MEM
634
MEM
636
DE-MUX
638
OUTPUT DATA SHUFFLING CONTROLLER
640
SELECT 3X PLAYBACK
641
OUTPUT FORMATTER
642
D-RDY
DATA
CLK
TO TELEVISION RECEIVER

FIG. 6